

Introduction
to
Advanced Accelerator HEP Program

Collider Studies & Advanced Studies

presented by
Swapan Chattopadhyay

DOE / HEP Review

April 11, 1996



Academic & Visiting Scientists

- Faculty Associates

- R. Falcone (lasers)
- J. Wurtele (beam physics)
- M. Shapiro (experimental laser-plasma detection)
- J. Siegrist (experimental laser-plasma detection)

- Visiting Scientists

- Y. Kishimoto, JAERI, Japan
- J. Koga, JAERI, Japan
- Y. Orlov, Cornell
- R. Ryne, LANL
- T. Tajima, UT Austin
- V. Telnov, BINP
- K. Yokoya, KEK

- Center Affiliates

- W. Barletta
- R. Gough
- A. Jackson
- R. Keller
- C. Kim
- D. Robin
- R. Schoenlein
- C. Shank
- H. Nishimura

- Participating Guests

- Five Emeriti scientists (A. Garren, G. Lambertson, J. Peterson, F. Selph, F. Voelker)
- L. Schachinger

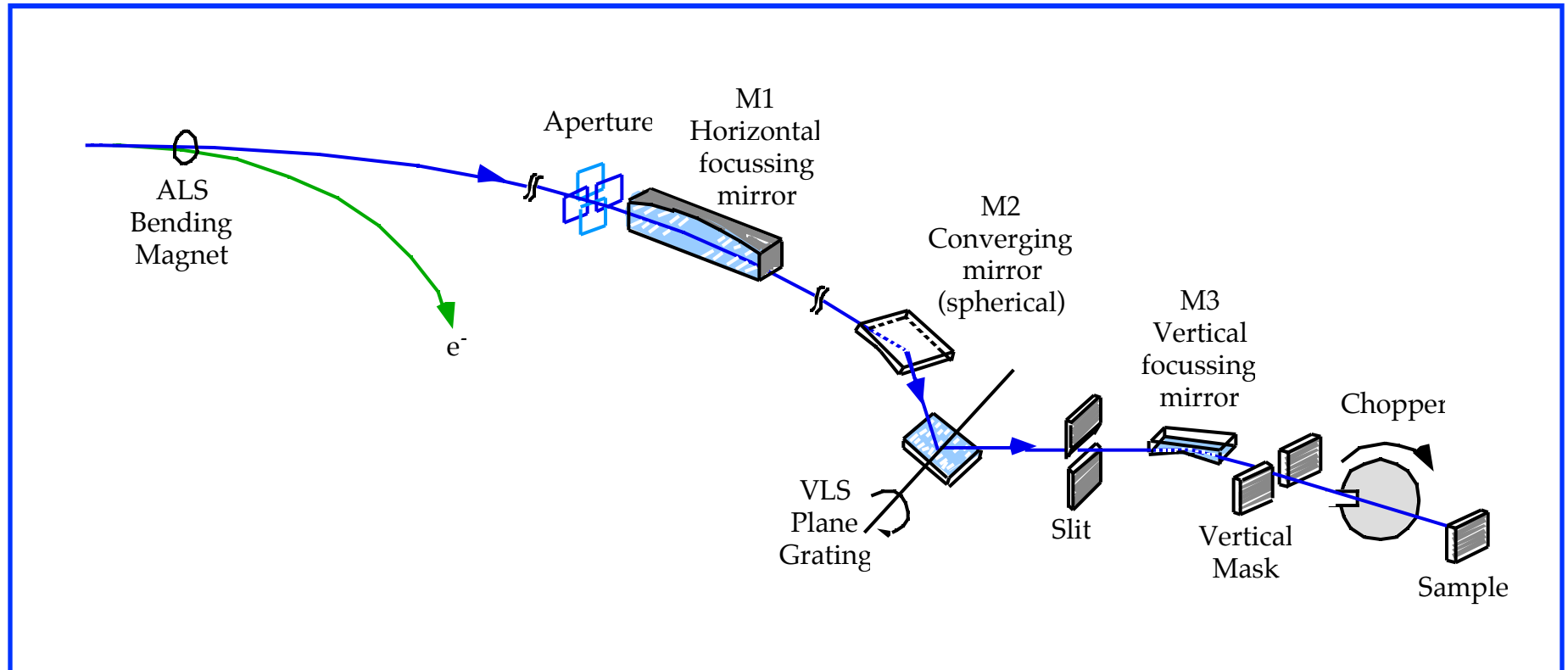


Advisory Committee for Experimental Program

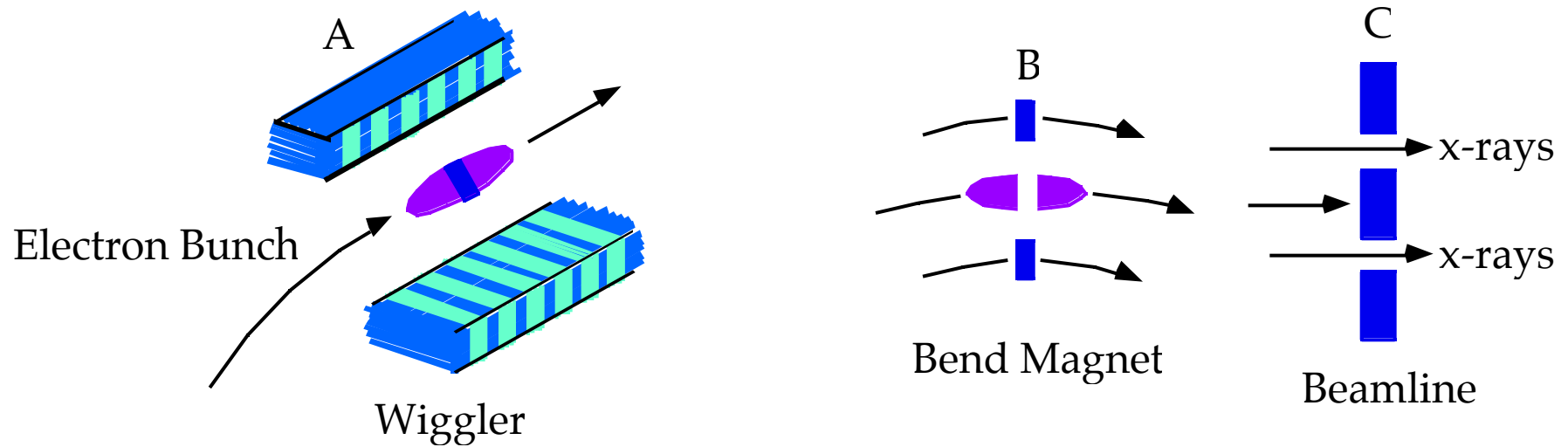
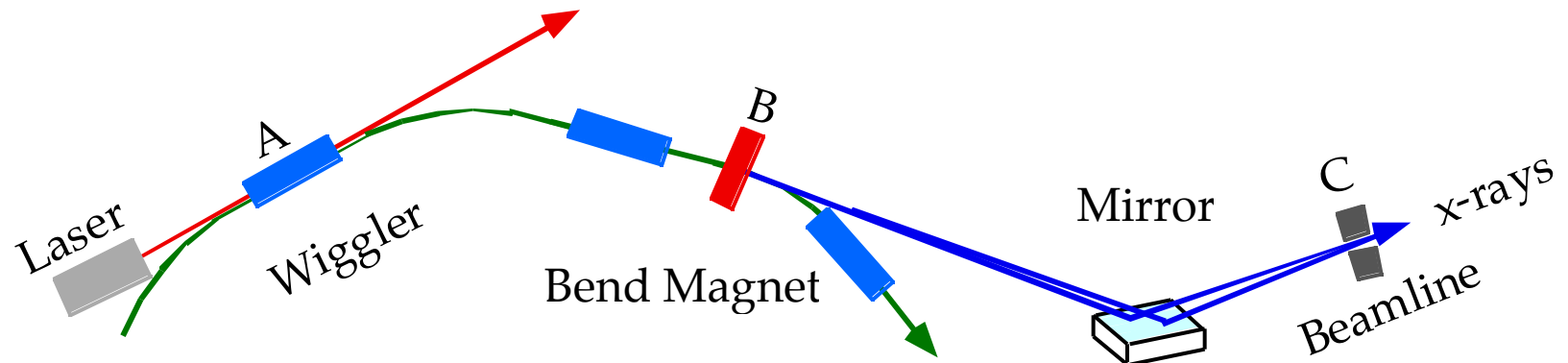
Advisory committee is formed to look into a prioritized list of initial set of experiments at the BTF and L'OASIS laboratory by researchers & students nationwide.

D. Burke, SLAC
E. Esarey, NRL
R. Falcone, UCB
C. Joshi, UCLA
N. Kroll, UCSD
G. Mourou, Univ. Michigan, Ann Arbor
R. Palmer, BNL
C. Pellegrini, UCLA
R. Rice, Cornell
D. Whittum, SLAC

Bending Magnet

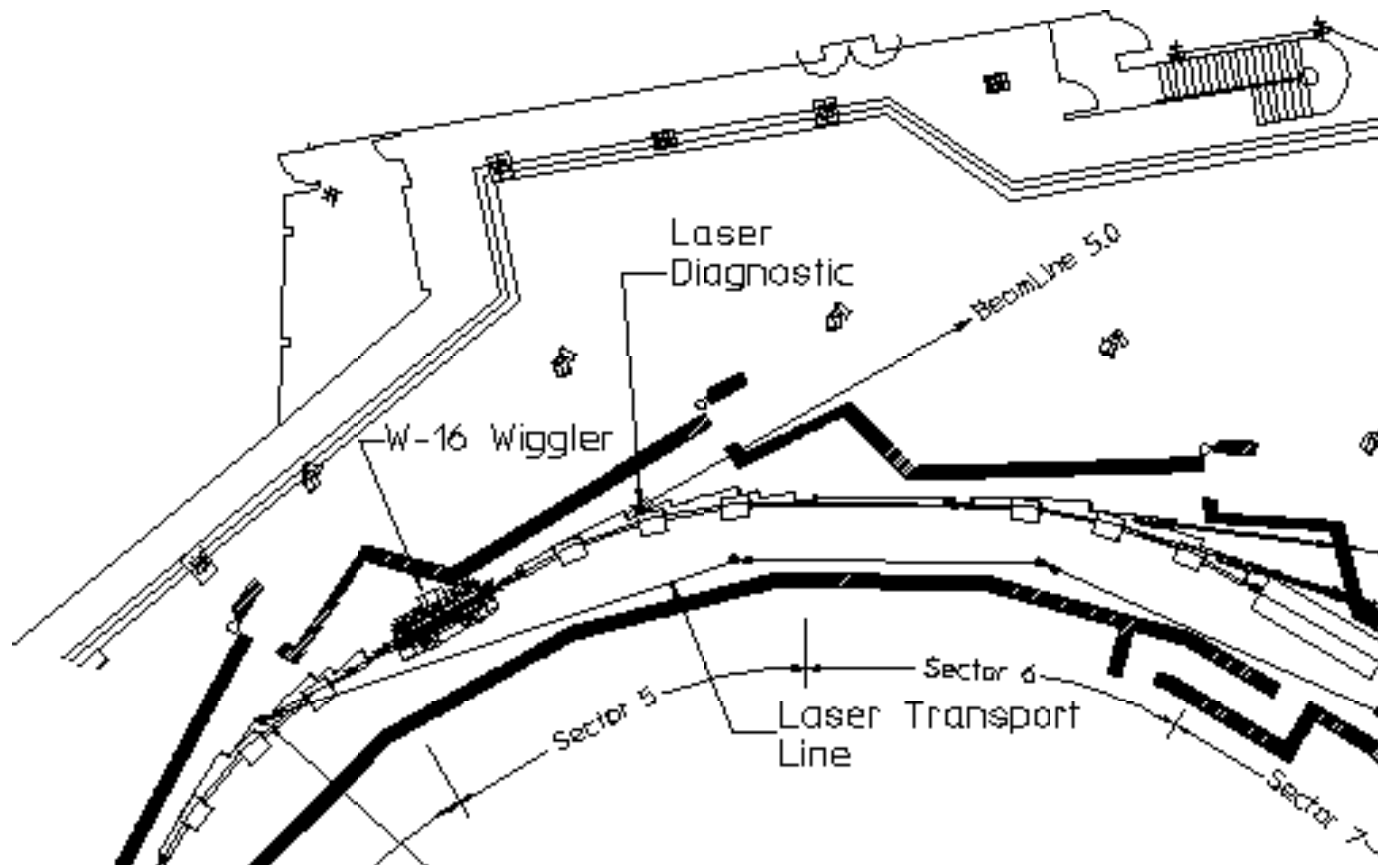


Electron Bunch





ALS Layout Implementation

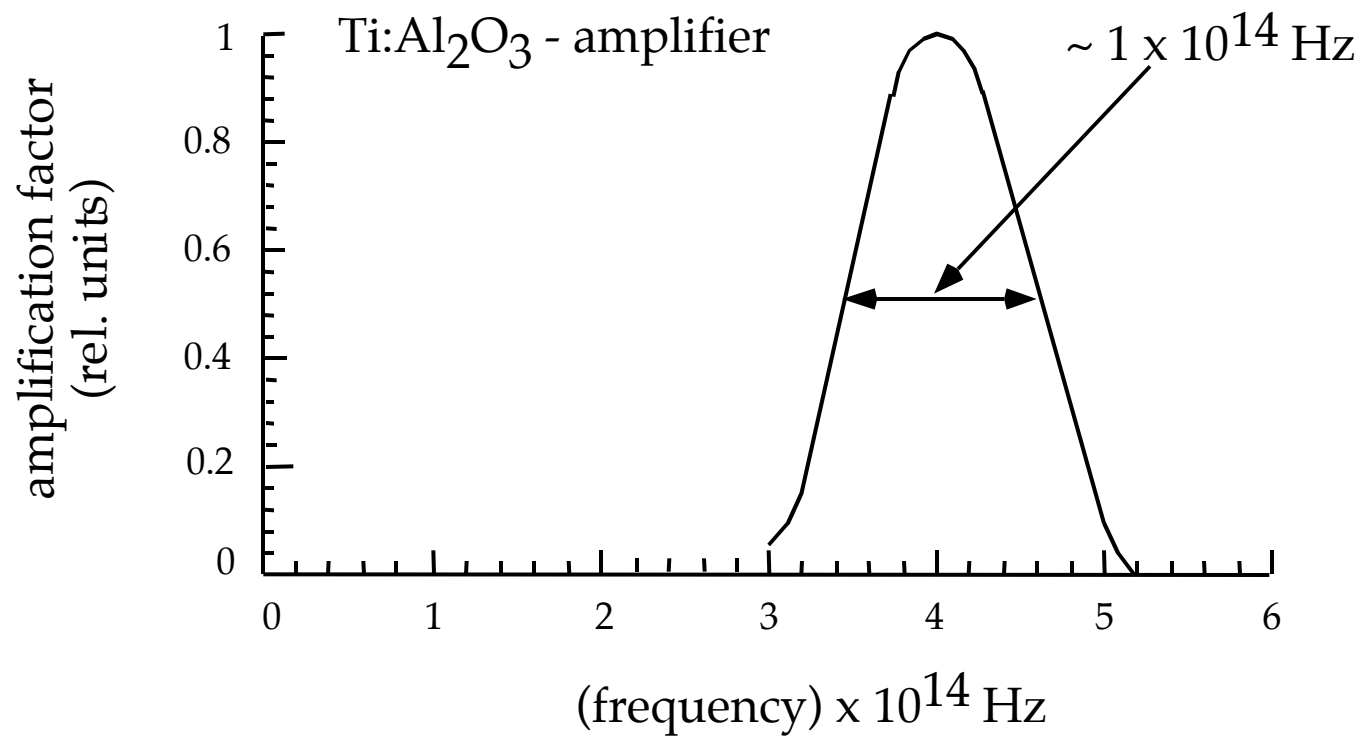




- Faraday Cup for Beam Instrumentation : W. Barry
- D. R. Nicholson Humanitarian Award (APS) : A. Sessler
- APS VP-Elect : A. Sessler
- APS Fellowships : W. Barletta, S. Chattopadhyay, K.-J. Kim

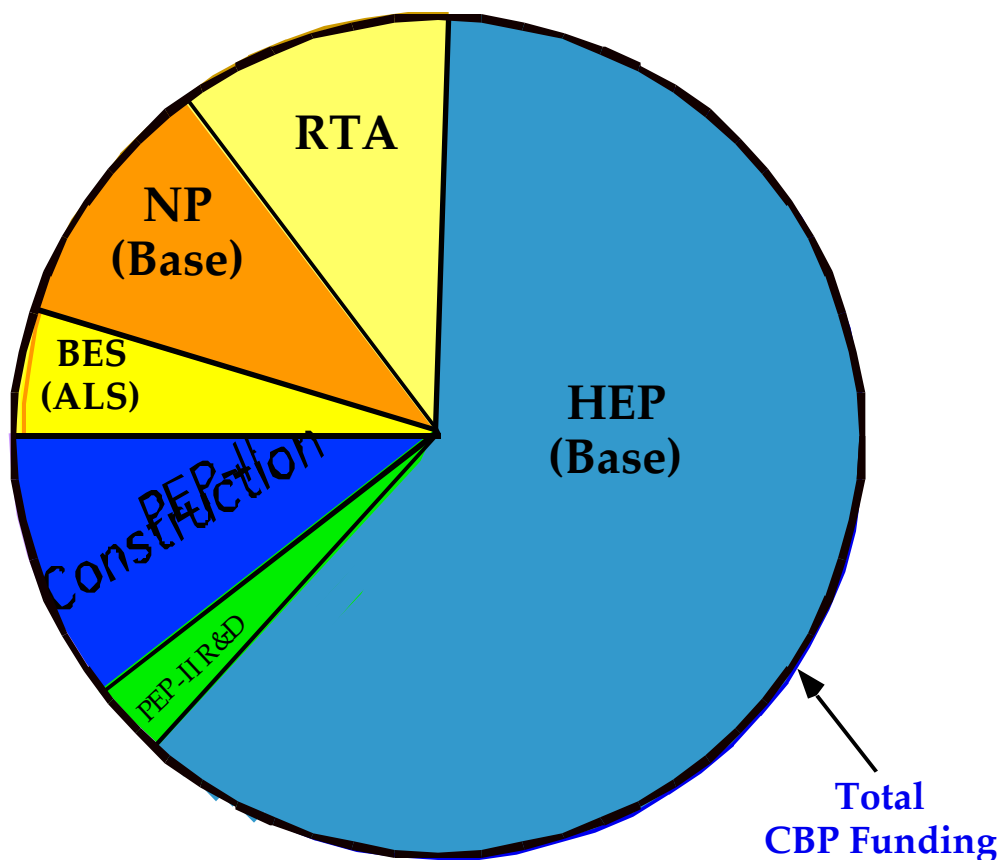


Broadband Optical Amplifiers (Ti:Al₂O₃, DYE)





Center for Beam Physics Budget & Effort FY 1996



Operating:

HEP Base: 2,525 k\$
 PEP-II R&D: 110 k\$
 PEP-II Constr. : 4 FTEs
 RTA : 570 k\$

Equipment:

HEP Base: 223 k\$
 (100k\$ held back due to PEP-II R&D funding shortfall)

PEP-II R&D: 40 k\$

BES (ALS): RF and Beam Control in the Advanced Light Source
 NP (Base): Phase Space Cooling of Heavy Ion Beams in RHIC (BNL)
 PEP-II : Asymmetric B-Factory at SLAC (SLAC-LBNL-LLNL)
 RTA : Relativistic Two-beam Accelerator



Consolidation of Experimental Infrastructure & Opportunities

- The Beam Test Facility will provide access to the 50 MeV electron beam from the ALS injector linac transferred via a magnetic transport line into a specially shielded experimental vault, for experimental R&D in HEP. Construction is complete. Beam commissioning on-going.
- Table-Top Terawatt laser already built via Laboratory Directed Research & Development funds. Another one already exists at the L'OASIS Laboratory.
- Components & plasma tests at the CBP L'OASIS Laboratory & the Lambertson Beam Electrodynamics Laboratory.
- Experimental plan fully developed.
- Local expertise in beam physics, plasma physics, high power & short pulse lasers, laser guiding, rf control & Quantum Optics is complete.



Consolidation of Experimental Infrastructure & Opportunities

- Advisory Committee formed.

With modest incremental operational support as requested in the FTP / A (2 FTEs/year & equipment funds of \$230 k\$/year), this will provide a highly cost-effective program in frontier accelerator R&D advancing HEP, competitive & complementary to other international and national efforts. If funded, it would yield definitive results in the next years on the following :

- Demonstration of guiding & confining high field gradients over long distances (1 GeV/m over a macroscopic length of a few cm to a meter).
- Detailed field & phase space dynamics mapping over the confined channel.



Educational Activities

- US Accelerator Schools :
 - UC San Diego, Winter '95-'96 (Beam Electrodynamics Group)
 - University of Maryland, Fall '96 (J. Byrd)
 - US-Japan Accelerator School, '96 (J. Byrd)
 - UC Berkeley, Winter '97 (planned)
- United Nations UNESCO School on Synchrotron Radiation, March '96 (K.-J. Kim)
- Regular graduate courses at UCB (Wurtele, Kim, Chattopadhyay)
- Graduate Seminar Class at UCLA (Barletta)
- CBP Seminars
- Editorship of Particle Accelerators & Nucl. Instr. Methods in Phys. Res. A
- Total number of students involved in program :
 - 11 graduate and undergraduate students altogether



Effort Breakdown

(HEP Advanced Accelerator R&D only)

FTEs

4 PEP-II Construction

3 PEP-II R&D (including 2.5 FTE from Base)

5 RF Power Source/RTA (including 2FTE from Base)

4 Accelerator Theory, Advanced Accelerator Methods, Lepton Colliders
& Experimental Program

2.5 Technical Associates

2 Administration

2 Students

Total : 22.5 (15 from HEP Base)



Experimental Facilities

- Beam Test Facility (BTF) at the ALS : Scheduled experiments and committee
- Lambertson Beam Electrodynamics Laboratory
- L'OASIS (Laser, Optics & Accelerator Systems Integrated Studies)
- - New facility under preparation
- Relativistic Two-beam Accelerator (RTA) Facility, Building 58



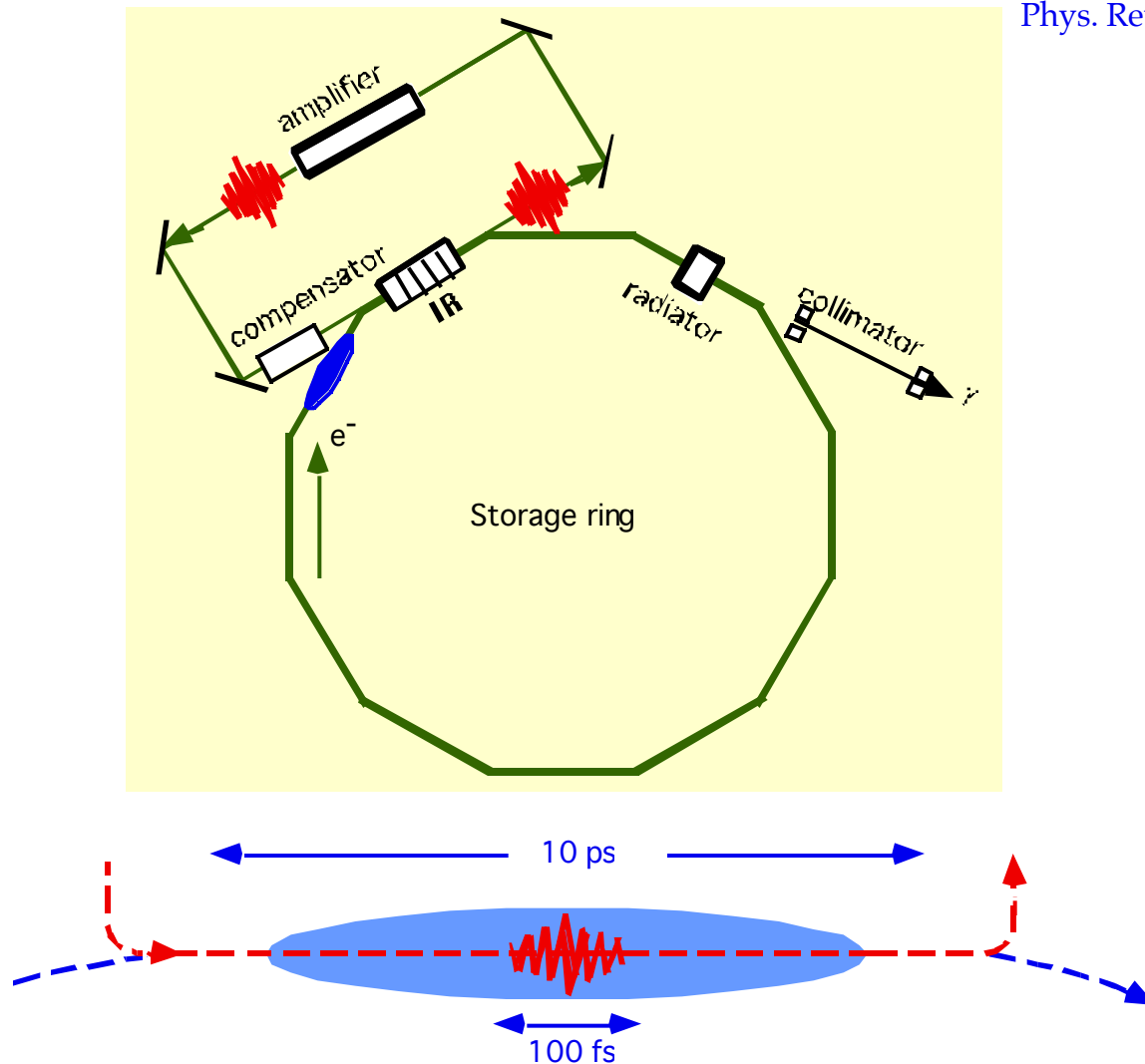
Experimental Program

- Beam Focussing
- Laser-Electron Beam Interaction
- Novel RF Structures
- Novel Diagnostic Techniques
- Laser Acceleration :
 - Generation of high gradients over long distances by laser-plasma wakefields (with guiding).
 - Systematic mapping of field configuration & dynamic phase-space acceptance of acceleration channel by high quality, spectrally pure beam.
- Optical Cooling & THz Signal Processing
- THz power sources



Femtosecond Slicing in a Storage Ring

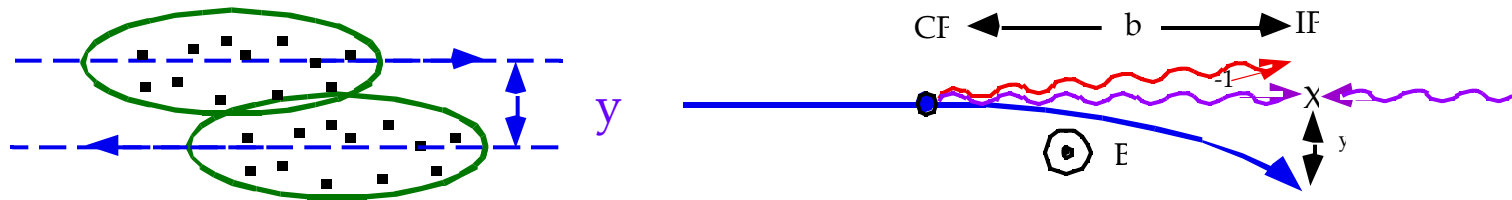
A.A. Zholents & M. Zolotarev,
Phys. Rev. Lett. 76, 916-918 (1996)





Luminosities in – Collision (V. Telnov)

	Collision with off-set		Sweeping Magnet ($b=0.78$ cm, $B=10$ kGs)
	$y = 0.5$	$y = 1$	
L_{ee}/L_{geom}	0.19	0.12	0
$L_{ee}(z>0.65)/L_{geom}$	0.114	0.064	0
L_e/L_{geom}	1.04	0.79	0.1
$L_e(z>0.65)/L_{geom}$	0.24	0.18	0.017
L_{γ}/L_{geom}	1.22	1.08	0.37
$L_{\gamma}(z>0.65)/L_{geom}$	0.112	0.103	0.09
$y_{max}[mrad]$	8	8	2.5





Major Milestones Achieved Major Milestones Achieved Major Milestones Achieved

Some major & exciting activities have taken place at LBNL in the last few years :

- PEP-II funded (SLAC/LBNL/LLNL) good prototype of a major collaboration. LBNL led the R&D in the formative stages (thanks to our HEP base program supported by DOE/HEP).
- Successful commissioning of the ALS (Advanced Light Source) at Berkeley : provides the platform and R&D base for PEP-II rf & Feedback systems as well as a prototype for a Damping Ring envisioned in future Linear Colliders.
- International Workshop on "Gamma-Gamma Colliders" @ LBL, March 1994.
- Successful design of a RTA^{TeV} prototype power source for a TeV Linear Collider & merging of LLNL-LBNL/RTA program to build & test a 30 m prototype @ LBNL & then @ NLCTA.
- Consolidation of expertise & resources in high power (Terawatt), short pulse lasers, plasmas, electron beams & optical guiding towards experiments on ULTRA-HIGH GRADIENT ACCELERATION & other advanced methods.



Memoranda of Collaboration and MOUs

- PEP-II (SLAC/LBL/LLNL)
- SLAC/LBL/LLNL on Next Linear Collider (NLC) ZDR
- CERN-CLIC/LBNL-CBP on Two -Beam Accelerator
- UC Davis/LBNL/SLAC - ATRI on Microwave Technology
- UC Davis-NEG/LBNL-CBP - AXF photocathode gun at 11.4 GHz

Informal collaboration with MIT on 17.4 GHz electron gun



POTENTIAL:

Memoranda of Collaboration and MOUs

- BINP-LBNL - Gamma-Gamma Collider
- LLNL-LBNL - High Average Power Lasers for HEP
- LBNL-BNL-FNAL - Muon Collider Studies
- LBNL-BNL-FNAL - LHC Studies
- CESTA-LBNL - Collaboration on TBA Studies



Outline

- Research Program
- Effort Breakdown
- Budget : FY 1996
- Staff Roster
- Experimental Facilities
- Memoranda of Collaboration and MOUs
- Research Output : Comments
- Major Milestones Achieved
- Consolidation of Experimental Infrastructure & Opportunities
- Experimental Program
- Educational Activities
- Sponsored Conferences & Workshops
- Awards & Honors
- Outstanding Budget Items
- Publications



Outstanding Budget Items

Year	Programs	Incremental Operating funds for the BTF	Incremental Equipment funds for the BTF	PEP-II R&D	Optical Cooling Beamline Equipment
FY '94	Requested	2 FTE	\$230 k	\$500 k	0
	Funded	0	0	\$150 k	0
FY '95	Requested	2 FTE	\$230 k	\$500 k	\$470k
	Funded	0	0	\$444 k	0
FY '96	Requested	2 FTE	\$230 k	\$700 k	\$470k
	Funded	0	0	\$110 k	0
FY '97	Requested	2 FTE	\$230 k	\$700 k	\$470k
	Funded	?	?	?	?



Reference design at $E_e = 250 \text{ GeV}$

i) Use beam parameters of e^+e^- design for IR1

$$N_e = 0.65 \times 10^{10}, \quad x = 4 \times 10^{-6} \text{ mrad}, \quad y = 7 \times 10^{-8} \text{ mrad}, \\ z = 0.1 \text{ mm}, \\ 90 \text{ bunches separated by } 1.4 \text{ ns, } 180 \text{ Hz}$$

ii) Modify FFS so the $x = y = 0.5 \text{ mm}$ $L_{\text{geom}} = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

iii) Use 1 J/pulse & $\bar{P}=16 \text{ kW}$ laser for 65% Compton conversion efficiency (photon energy up to 200 GeV)

v) CP - IP distance 5 mm to suppress the low energy luminosity

iv) Variable electron and laser polarization

$$L = (\text{Compton})^2 (\text{Monochromatization}) \\ 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$$

vi) Sweeping magnet between CP and IP will reduce background collisions



Research Output : Comments

- Large student participation & training
- Publications : many
- Leading contributions to initiatives in HEP :
 - PEP-II : new program launched in US-HEP
 - Gamma-Gamma IR in Linear Colliders
- General contributions to High Energy Physics :
 - FNAL (\bar{p} source, cooling) ; permanent magnet storage ring for antiproton accumulation
 - SSC 1980-84 : Snowmass studies, etc.
 - 1984-88 : Central Design Group
 - 1988-93 : Consulting + magnets + detailee, etc.
 - PEP-II : initiated & now funded
 - LHC/NLC : continuing
 - Advanced accelerator concepts & beam physics experimental program : continuing

Research Output.....con't



Research Output : Comments (con't)

- Many advanced tools & state-of-the-art codes developed & shared with community towards collider conception & design e.g., codes & methodologies for nonlinear dynamics in collider rings based on modern analytical & numerical algorithms based on Lie - and Differential-algebraic techniques, symplectic integration, etc. Complete set of codes already used by other HEP labs (CERN, SSC /LHC, SLAC, BNL, KEK, FNAL, DESY, etc) : TRACY-II, THOR, DAPASCAL, Six Track, ZAP, ABCI, MOSES.
- Beam Test Facility (BTF): Advanced Experimental Facility made available to the HEP community for carrying out forefront R&D in advanced accelerator concepts in support of colliders of the future. (W. Leeman's talk)
- New facility under preparation : L'OASIS (Laser-Plasma, THz & Quantum Optics for HEP studies).
- Industrial Collaboration : Haimson Research, Inc. on advanced accerator rf development.
- Integrated with National Effort on US-CERN collaboration on the LHC & member of the International Collaboration on Linear Colliders via Interlaboratory MOU. Integrated with National Effort on Muon Colliders



Research Program

- Hadron Collider Frontier:
 - TeV* (0.5 FTE)
 - RLHC, LHC (1.0 FTE)
- Lepton Collider Frontier:
 - PEP-II B-Factory (3 FTE+ 4 FTE construction)
 - NLC: e^+e^- , Gamma-Gamma and Muons (5 FTE)
 - Two Beam Accelerator (2 FTE + 3 FTE RTA project)
- Advanced Technologies:
 - Experimental Program at the BTF (4 FTE)
 - New Thrust: Laser Manipulation of Beams (~1.5 FTE)



Sponsored Conferences and Workshops

- Mini Workshop on Laser Acceleration — 1995
- Ettore Majorana @ Erice on High Field Superconducting Magnets — 1995
- ICFA Nonlinear Dynamics Workshop — 1996
@ Arcidosso, Italy together with SLAC and UCLA
- Advance Accelerator Workshop — 1996 @ Lake Tahoe
(sponsored by DOE/HEP)
- Superconducting Magnet — 1996
- RLHC — November 1996



Staff Roster

Scientists & Engineers :

BARRY, Walter
BYRD, John
CHATTOPADHYAY, Swapan
CORLETT, John
FAWLEY, William
FURMAN, Miguel
GOLDBERG, David
JOHNSON, Jimmie
KIM, Kwang-Je
LEEMANS, Wim
RIMMER, Robert
SESSLER, Andrew
TURNER, William
XIE, Ming
YU, Simon
ZHOLENTS, Alexander
ZISMAN, Michael
ZOLOTOREV, Max

Post-Docs :

CHENG, Wen-Hao
SHADWICK, Brad

Technical Support :

ARCHAMBAULT, Leon
LOZANO, David
DOUGHERTY, Jim

Administrative Support :

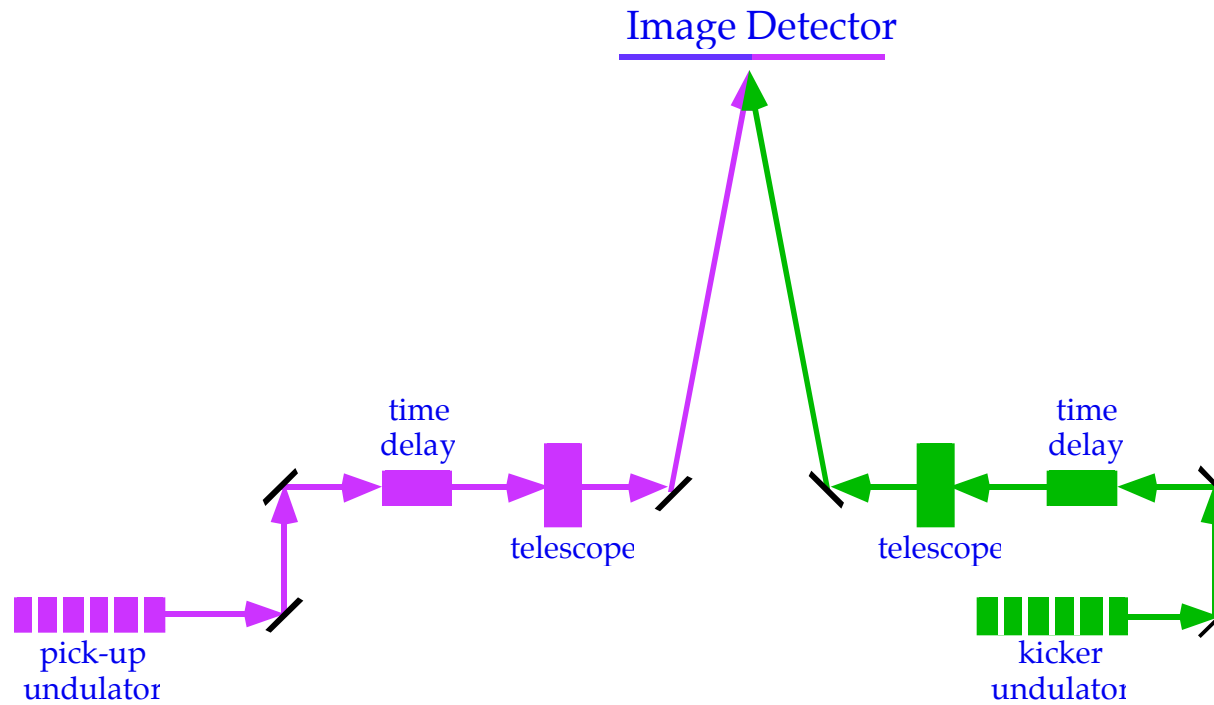
KONO, Joy
VANECEK, "Sam"
WONG, Olivia

Students :

BACCHUS, Ian
BRYANT, Tyler
DRAESEKE, Andrew
FAIGUENBLAT, Mikhail
GOVIL, Richa
IRWIN, Mike
LEE, Peter
LIE, James
PONCE-MARQUES, David
SCHROEDER, Carl
VOLFBEYN, Paul

(funded by UCB)

Test of "Non-Mixing" via Fringe Visibility



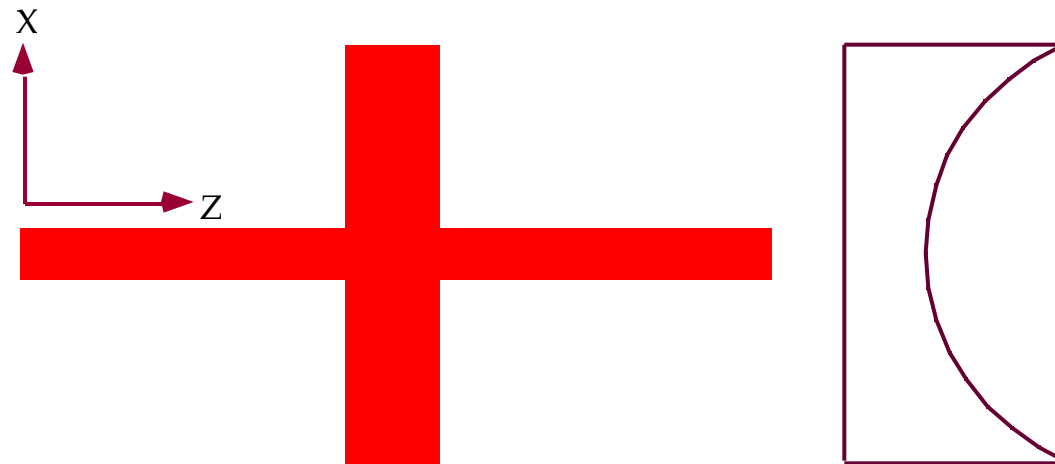
Preservation of fluctuations in the electron beam in the passage between undulators. Visibility of the interference pattern :

$$\text{Visibility} = \exp - \frac{(k \ell')^2 + (k \ell)^2}{2}$$



*Today we are contemplating replacing the GHz microwave rf technology by state-of-the-art short pulse high power compact lasers as work horses for particle accelerators. There exist possibilities of generating ultrahigh electromagnetic fields by coupling today's lasers either to a suitably formed plasma or to channel in free space with suitable boundaries. However, just as in today's microwave technology involving beam manipulation over fractions of **mm**s in time-scales of **picoseconds** at frequencies of **GHz**, one would have to learn to manipulate and control signals and particles at optical wavelengths of **microns**, in time-scales of **femtoseconds** at frequencies of **THz** and higher in order to take advantage of today's lasers. For example, the development of femtosecond kickers, choppers, bunch rotators etc., and THz manipulation of beams will be one of the most challenging jobs for beam scientists, but needs to be accomplished for further progress.*

- Electrons (previously energy modulated) will be spatially separated in a dispersive region



- Top view on a fraction of the electron bunch and particle density distribution in the horizontal plane